CONNECTIVITY BETWEEN KACHEMAK BAY AND THE GULF OF ALASKA

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ABSTRACT

Kachemak Bay is a fjord estuary near the mouth of Cook Inlet, Alaska. Historical measurements of circulation in Lower Cook Inlet indicate the presence of an anticyclonic gyre in the mouth of Kachemak Bay. This gyre opposes the flow of Alaska Coastal Current (ACC) waters from the Gulf of Alaska into Kachemak Bay. Remote sensing and modeling results indicate the presence of this gyre forms a plug in the mouth of Kachemak Bay during the spring. Later in the summer the gyre relaxes or moves northward allowing Gulf water to enter the Bay. This connection to the Gulf allows larvae to replenish populations within Kachemak Bay. Organisms with larval forms in the spring are excluded from the Bay except in very episodic occurrences. Therefore populations in Kachemak Bay that have springtime larval forms must be managed as isolated stocks.

LOCATION

Kachemak Bay is located near the mouth of Cook Inlet, Alaska (Figure 1). A spit at Homer on the northern side of the Bay extends four miles (~half way across) into the bay separating the bay into inner and outer portions. A deep (>100m) trench runs from the mouth of the Bay to the spit.

Important factors that influence the circulation within Kachemak Bay include a large tidal range and freshwater inputs. The mean tidal range is approximately 5m and 8m maximum tidal range, which strongly influences local circulation. Glacial melt water feeds several small rivers that flow into the south side and head of the bay. The freshwater tends to circulate cyclonically around the inner bay and hug the northern boundary as it passes through the outer bay.

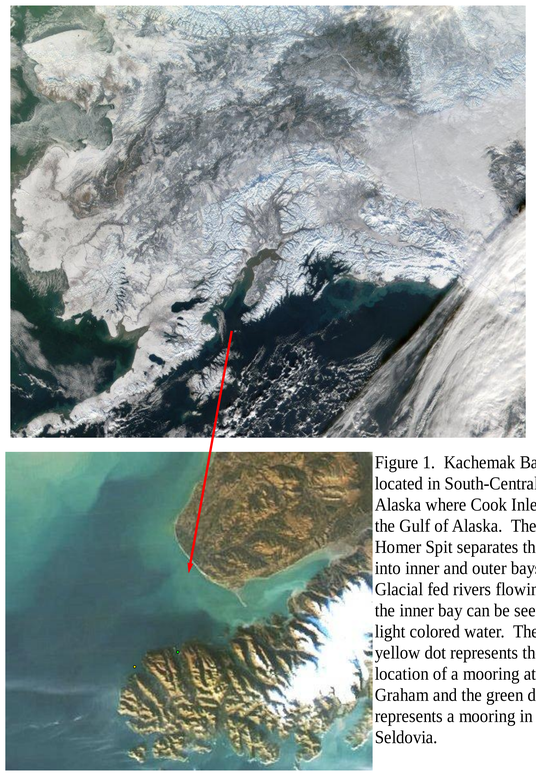


Figure 1. Kachemak Bay is located in South-Central Alaska where Cook Inlet meets the Gulf of Alaska. The Homer Spit separates the Bay into inner and outer bays. Glacial fed rivers flowing into the inner bay can be seen as light colored water. The yellow dot represents the location of a mooring at Port Graham and the green dot represents a mooring in Seldovia.

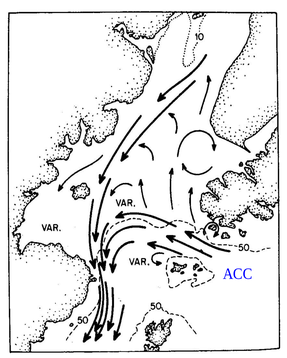


Figure 2. Circulation patterns in Lower Cook Inlet as described by Muench et al. [1978]. Major features include the intrusion of the Alaska Coastal Current into the mouth of Cook Inlet, the freshwater driven current along the western side, and a anticyclonic gyre in the mouth of Kachemak Bay.

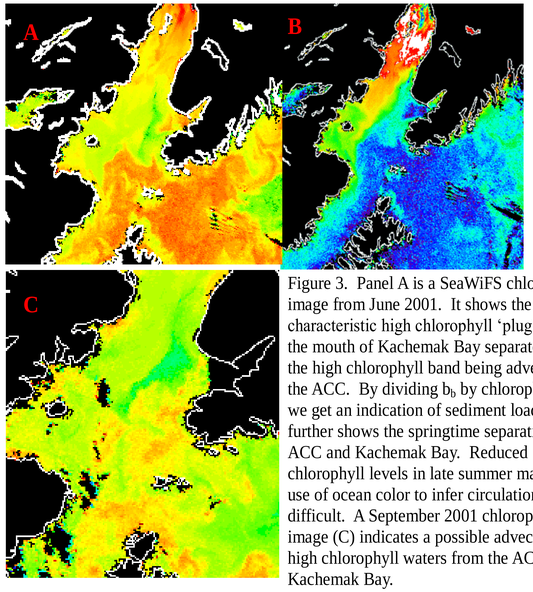


Figure 3. Panel A is a SeaWiFS chlorophyll image from June 2001. It shows the characteristic high chlorophyll 'plug' within the mouth of Kachemak Bay separated from the high chlorophyll band being advected by the ACC. By dividing b_b by chlorophyll (B) we get an indication of sediment loading that further shows the springtime separation of the ACC and Kachemak Bay. Reduced chlorophyll levels in late summer make the use of ocean color to infer circulation more difficult. A September 2001 chlorophyll image (C) indicates a possible advection of high chlorophyll waters from the ACC into Kachemak Bay.

MEASUREMENTS AND MODEL RESULTS

Historical

Most of the research on circulation in Lower Cook Inlet, including Kachemak Bay, occurred in the early 1970s. Circulation maps were inferred from hydrographic transects and current meter moorings by Muench et al. [1978] (Figure 2) and drogued drifters and drift cards by Burbank [1977]. While there are differences between the inferred circulation by the two studies, they both indicate the presence of a anticyclonic gyre at the mouth of Kachemak Bay that opposes the inflow of water from the Gulf of Alaska. The size and exact position of the gyre differ in the two studies. The strong current on the west side of Cook Inlet and the intrusion of the main stream of the Alaska Coastal Current into Lower Cook Inlet have been confirmed by a number of methods.

Recent Findings

More recently, ocean color satellite and numerical modeling results have been used to examine the circulation in Lower Cook Inlet. In the spring, chlorophyll as determined from ocean color satellite can be used to infer some aspects of circulation. In the spring it is common to observe a triangular "plug" of chlorophyll at the entrance to Kachemak Bay (Figure 3a). The high chlorophyll in Kachemak Bay is separated from the high chlorophyll entering into Cook Inlet by a band of clearer water. Examining backscatter/chlorophyll (Figure 3b) shows the disconnect between the ACC and Kachemak Bay. Determination of circulation from imagery later in the summer is hampered by persistent cloud cover and lower surface chlorophyll values. Images during the fall bloom show a pattern suggestive of ACC water entering into Kachemak Bay.

Numerical modeling of the circulation of the region was completed using a nested Regional Ocean Model System (ROMS) with 30 vertical layers and 4 km horizontal resolution. A freshwater line source is applied to the regions in the Gulf of Alaska to simulate the many small streams flowing in the area. Tidal forcing is included, but freshwater sources in Cook Inlet are not present in these model runs. Wind forcing is based on NCEP climatology. The model produces a circulation pattern similar to that inferred from the remote sensing imagery. It provides a much clearer picture of the development of a connection between the ACC and Kachemak Bay during the summer. Starting in early July and building through October the model shows intrusions of fresher water entering into Kachemak Bay. In July the intrusions are episodic and shift to more continuous later in the year.

The Kachemak Bay Research Reserve maintains bottom moored CTDs within Kachemak Bay as part of the National Estuarine Research Reserve System Wide Monitoring Program (SWMP). Two of the sensors are located near Port Graham and Seldovia (Figure 1). Salinity measurements from these moorings are shown in Figure 5. In 2002 it can be seen that there is a large decrease in salinity in mid-August; the lower salinity water being associated with the ACC as it intrudes into Kachemak Bay. As should be expected the fresher water passes Port Graham a couple days before reaching Seldovia. In 2003 the decrease in salinity at Seldovia occurred a couple weeks earlier than in 2002. These observations are consistent with the model results.

Currently there are CODAR units and drogued drifters measuring the circulation patterns in the region. The addition of these technologies will provide more information on the circulation patterns of Lower Cook Inlet.

Figure 4. ROMS modeling of circulation in Lower Cook Inlet and the Gulf of Alaska are presented. Solid lines indicate the bathymetry, arrows represent surface water flow with the length being proportional to strength, the color is based on the salinity anomaly with blues indicated fresher water. Hourly model results have been averaged over two days to reduce tidal effects. The model results are similar to that inferred from the satellite imagery. The core of the ACC passing across the mouth of Cook Inlet with fresh water intrusions into Kachemak Bay beginning in July or August.

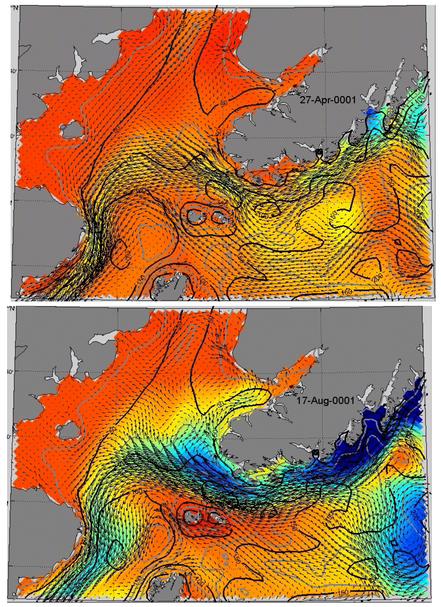
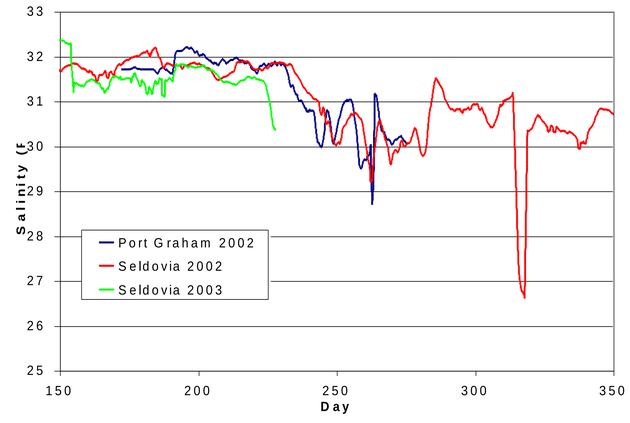


Figure 5. Salinity measurements from bottom (~15m deep) mounted moorings at Port Graham and Seldovia. A sharp decrease in salinity is observed in 2002 and 2003 during August. The salinity at Seldovia lags the decrease at Port Graham by approximately 2 days. This gives an incursion speed of 0.1 m/s. The earlier decrease in salinity at Seldovia in 2003 provides a hint of the interannual variability in the arrival of the ACC within Kachemak Bay.



DISCUSSION

The recent satellite imagery and model results support the historical view of the existence of an anticyclonic gyre in the mouth of Kachemak Bay. This gyre is probably stretched by the strong tides and bounded by the topographically controlled rips in Cook Inlet giving it a non-circular appearance. It is probably smaller and more enclosed by the bay than shown by Muench et al. As freshwater input into the Gulf of Alaska increases over the summer the strength of the ACC increases. By July the ACC becomes fresh and strong enough to begin to pulse into Kachemak Bay providing water from the Gulf of Alaska. Despite the high tidal flux the presence of the local spring phytoplankton bloom within Kachemak Bay indicates poor exchange of water with Cook Inlet and the Gulf of Alaska. It is interesting to note that satellite imagery indicates that a portion of the Kachemak Bay bloom travels northward with the local freshwater driven current, but it has not been seen to travel west across Cook Inlet with the ACC.

The presence of the gyre has important biological implications. The gyre acts as a plug in the spring preventing exchange of waters with the ACC. Organisms with a spring larval stage therefore are not normally brought into Kachemak Bay. The local organisms are dependent on retention of their larvae to replenish stocks and therefore must be managed as isolated stocks. Once a stock, such as Dungeness Crab, are depleted the reintroduction of the species will depend on an unusual set of conditions that allow ACC water to pulse into Kachemak Bay. The necessary conditions may occur if heavy rains in the spring cause the ACC to increase in strength earlier in the year.

REFERENCES

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